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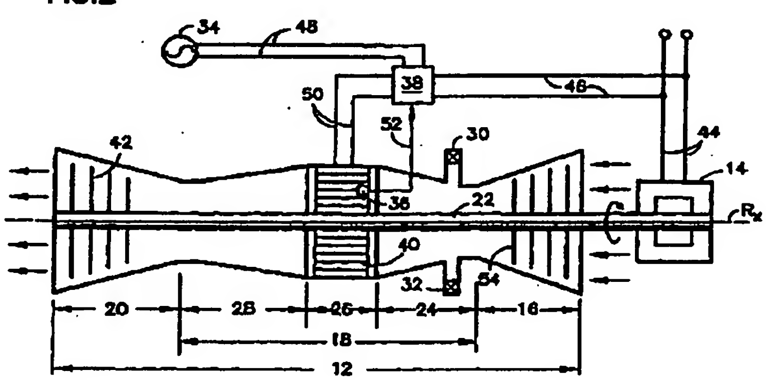
(54) A gas turbine with a catalytic combustor and method of operating such a gas turbine

(57) The present invention is a method and apparatus for operating a gas turbine that includes a catalytic combustor. The catalyst in the catalytic combustor is electrically heated, thereby initiating catalytic combustion without preheating the intake air. Eliminating the need to preheat the intake air allows removal of the preburner which otherwise produces an undesirable amount of oxides of nitrogen NO_x, especially at start up and low load conditions.

FIG.2



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Description

Technical Field

[0001] This invention relates to a gas turbine and more particularly to a method of operating a gas turbine, which includes a catalytic combustor.

Background Art

[0002] An axial flow rotary machine, such as an industrial gas turbine for a co-generation system or a gas turbine engine for an aircraft, includes a compressor section, a combustion section, and a turbine section. As the working medium gases travel along the flow path, the gases are compressed in the compressor section, thereby causing the temperature and pressure of the gases to rise. The hot, pressurized gases are burned with fuel in the combustion section to add energy to the gases, which expand through the turbine section and produce useful work and/or thrust.

[0003] The burning of fuel, however, causes the gas turbine to emit undesirable oxides of nitrogen (NO_x). Regulations limiting the amount of NO_x emissions produced by gas turbines has motivated the development of certain technologies such as diluent injection in the combustion section, lean premixed Dry Low NO_x (DLN) combustion and catalytic combustion. A conventional catalytic combustor typically includes a precombustion zone, a premixing zone, a catalyst zone and a combustion zone. The catalyst zone includes a catalytic reactor, which includes a catalyst. A typical precombustion zone includes a preburner, which increases the temperature of the working medium gases in order to initiate and maintain the catalytic reaction between such gases and the catalyst. In this case, however, the preburner is the leading producer of NO_x, especially during start-up and low load operations when the preburner is required.

Disclosure of Invention

[0004] An object of the present invention includes eliminating the pre-combustion zone of a catalytic combustor in a gas turbine, thereby reducing the pollutants created by a gas turbine during operation, especially during start-up and low load operation.

[0005] Accordingly the present invention includes a method for operating a gas turbine, which contains a catalytic combustor, wherein such method comprises heating a catalyst within the catalytic combustor to a predetermined temperature thereby activating catalytic combustion of a fuel-air mixture. Such method includes electrically heating the catalyst when the temperature of the catalyst falls below the predetermined temperature, namely upon starting the gas turbine and/or partial load conditions during operation. Electrically heating the catalyst reduces the intake air temperature required to initiate combustion, thereby reducing and/or eliminating the requirement of preheating the intake air. Eliminating the preburner, therefore, improves the simplicity and control of operating the gas turbine. A method of electrically heating the catalyst includes connecting a generator to the gas turbine, thereby generating electricity which is directed to a portion of the catalyst when the catalyst falls below the predetermined temperature. Redirecting electricity to the catalyst and back into the gas turbine provides efficient operation of the gas turbine.

[0006] An additional or alternate embodiment of a method for electrically heating the catalyst includes providing a portion of the catalyst with electricity from an auxiliary power supply.

[0007] The present invention further includes a gas turbine as specified in claim 6. Preferably, such gas turbine consists essentially of the elements (a), (b), (c), and (d).

[0008] The present invention also includes a catalytic combustor consisting essentially of a premixing zone, a catalyst zone having a catalyst therein, a combustion zone, and means for electrically heating a portion of the catalyst to a predetermined temperature. The catalyst zone is disposed between the premixing zone and the combustion zone. Inclusion of the means for heating a portion of the catalyst eliminates the requirement of a pre-combustion zone, thereby removing such zone and the cause of a significant portion of the pollutants created when operating a gas turbine.

[0009] The foregoing and other objects, features and advantages of the present invention will become more apparent in light of the following detailed description of exemplary embodiments thereof as illustrated in the accompanying drawings.

Brief Description of Drawings

[0010]

Fig. 1 is an illustration of an electric power generating system which includes an industrial gas turbine engine and generator.

Fig. 2 is a schematic diagram of a gas turbine of the present invention equipped with an electrically heated catalytic combustor.

Best Mode for Carrying out the Invention

[0011] Although the present invention is described in relation to an industrial gas turbine, the present invention can also apply to any gas turbine engine application.

[0012] Referring to Fig. 1, the electric power generating system **10** includes an industrial gas turbine **12** that drives a generator **14**. The generator **14** can be used to drive local electrical needs or connected to a power grid network. The industrial gas turbine **12**, however, is not limited to driving an electrical generator **14**. The gas turbine can also be used to drive other types of

loads.

[0013] Referring to Fig. 2, the industrial gas turbine 12 is axially located along axis (R_x) and includes a compressor section 16, a combustion section 18, a turbine section 20 and a shaft 22. The combustion section 18 is a catalytic combustor, which includes a premixing zone 24, a catalyst zone 26, and a combustion zone 28. Intake air enters the compressor section 16, and fuel enters the premixing zone 24 of the combustion section 18 through fuel supply lines 30, 32 and mixes with the intake air, thereby creating a combustible fuel-air mixture. The fuel-air mixture enters the catalyst zone 26 where combustion of the mixture is initiated and continues to completion in the combustion section 28, thereby adding energy to the working medium gas. The turbine section 20 includes a turbine, indicated by lines 42, which rotates as the heated gas expands through this section. The turbine 42 is connected to one end of the shaft 22, which transmits power to the compressor 54 and the generator 14. When the turbine 42 rotates, the shaft 22 also rotates, thereby enabling the generator 14 to produce electricity, which travels along lines 44.

[0014] The catalyst zone 26 includes a catalytic reactor 40 and a temperature sensor 36. The catalytic reactor 40 contains a ceramic or metal honeycomb catalyst matrix, which may be wash-coated with alumina, stabilized alumina or a similar catalyst substrate. The wash-coated catalyst substrate is impregnated with an active catalyst material, such as one or more of the precious metals or a combination of precious metals that are capable of withstanding the combustion temperature of the catalytic reactor. Certain types of precious metals that are catalytically active and capable of withstanding elevated temperatures include platinum, palladium, and rhodium.

[0015] Upon sensing that the temperature of the catalytic reactor 40 is less than a predetermined temperature, the temperature sensor 36 delivers a signal along line 52 to the controller 38. The controller 38, in turn, delivers electric current via lines 50 to the catalytic reactor 40, thereby elevating the temperature of at least a portion of the catalytic reactor 40 to the predetermined temperature. It is preferable to elevate the temperature of the portion of the catalytic reactor 40 nearest the premixing zone 24, which is referred to as the inlet portion, in order to initiate catalytic combustion as early as possible within the catalytic reactor 40. The predetermined temperature is dependent upon the type of catalyst, the type of fuel and the fuel-air composition. The predetermined temperature, however, is a temperature at or above the catalyst light-off temperature, wherein the catalyst light-off temperature is a temperature sufficient to initiate and maintain catalytic combustion. Maintaining at least a portion of the catalytic reactor 40 at the predetermined temperature ensures that the fuel-air mixture will combust within the combustion zone 18. The heat generated by the combustion, in turn, increases the temperature of the catalytic reactor 40, thereby sustaining catalytic combustion.

[0016] The temperature sensor 36 senses the temperature of the catalytic reactor 40 and sends a signal to controller 38 along line 52. Upon sensing that the catalytic reactor 40 has attained the predetermined temperature, the controller discontinues or reduces (i.e., modulates) the amount of electricity delivered to the catalytic reactor 40 as necessary to maintain the catalyst temperature at or above the predetermined temperature. If the catalyst matrix of the catalytic reactor 40 is constructed of ceramic, then the electric current will have to be applied to an electrically conducting material within or on the ceramic. If the catalyst matrix is constructed of metal, then the electric current will be applied directly to the support structure.

[0017] The controller 38 is capable of receiving electricity from both the generator 14, along lines 44 and 46, and an auxiliary power supply 34 (e.g., auxiliary generator) along lines 48. At start-up and at low load conditions, the generator 14 may not produce a sufficient amount of electricity to heat the catalytic reactor 40 to the predetermined temperature due to the lack of rotational shaft speed. The auxiliary power supply 34, therefore, provides the controller 38, along lines 48 with additional electricity during such operating conditions. The controller 38, in turn, furnishes the catalytic reactor 40 with the necessary power to maintain the catalytic reactor 40 at the predetermined temperature until the generator 14 independently produces a sufficient amount of electricity to maintain the temperature of the catalytic reactor 40 above the predetermined temperature. Re-directing the electricity generated by the generator 14 to the catalytic reactor 40 provides for an efficient co-generation system 10.

Claims

1. A method for operating a gas turbine, the gas turbine extending axially and having an upstream end and a downstream end, a compressor section, a catalytic combustor section and a turbine section, the compressor section being relatively toward the upstream end, the turbine section being relatively toward the downstream end, the catalytic combustor section disposed between the compressor section and the turbine section, the catalytic combustor section having a premixing zone, a catalyst zone and a combustion zone, the premixing zone being relatively toward the compressor section, the combustion zone being relatively toward the turbine section, the catalyst zone disposed between the premixing zone and the combustion zone and having a catalyst therein, comprising the steps of:

   (a) introducing intake air into the compressor section;
   (b) allowing the intake air to enter the mixing zone of the catalytic combustor section;

(c) introducing fuel into the mixing zone and creating a fuel-air mixture which enters the catalyst zone; and

(d) heating at least a portion of the catalyst to a predetermined temperature, thereby initiating catalytic combustion of the fuel-air mixture.

2. The method of claim 1 further comprising the step of heating the portion of the catalyst to said predetermined temperature when the temperature of the catalyst falls below the predetermined temperature.

3. The method of claim 1 or 2, wherein the step of heating the portion of the catalyst comprises electrically heating the portion.

4. The method of claim 3 wherein the step of electrically heating a portion of the catalyst comprises the steps of connecting a turbine, within the turbine section, to a shaft; rotating the turbine and the shaft; generating electricity from the rotating shaft; and directing at least a portion of the generated electricity to the portion of the catalyst.

5. The method of claim 3 or 4 wherein the step of electrically heating a portion of the catalyst comprises applying electricity to the portion from an auxiliary power supply.

6. A gas turbine extending axially and having an upstream end and a downstream end, comprising:

(a) a compressor section being relatively toward the upstream end;

(b) a turbine section being relatively toward the downstream end;

(c) a catalytic combustor section disposed between said compressor section and said turbine section, said catalytic combustor section consisting essentially of a premixing zone, a catalyst zone and a combustion zone, said premixing zone being relatively toward said compressor section, said combustion zone being relatively toward said turbine section, said catalyst zone disposed between said premixing zone and said combustion zone, said catalyst zone comprising a catalyst therein; and

(d) means for heating at least a portion of said catalyst to a predetermined temperature.

7. The gas turbine of claim 6 wherein said means for heating comprises:

(a) a turbine within said turbine section;

(b) a shaft connected to said turbine;

(c) a generator connected to said shaft, said generator generating electricity when said turbine rotates; and

(d) a controller which directs electricity from said generator to said portion of said catalyst when the temperature of said catalyst is less than said predetermined temperature.

8. The gas turbine of claim 6 or 7 wherein said means for heating comprises an auxiliary electrical power supply and a controller which directs electricity from said auxiliary electrical power supply to said portion of said catalyst when the temperature of said catalyst is less than said predetermined temperature.

9. The gas turbine of any of claims 6 to 8 wherein said catalyst is a material from the group consisting essentially of platinum, palladium and rhodium.

FIG.1

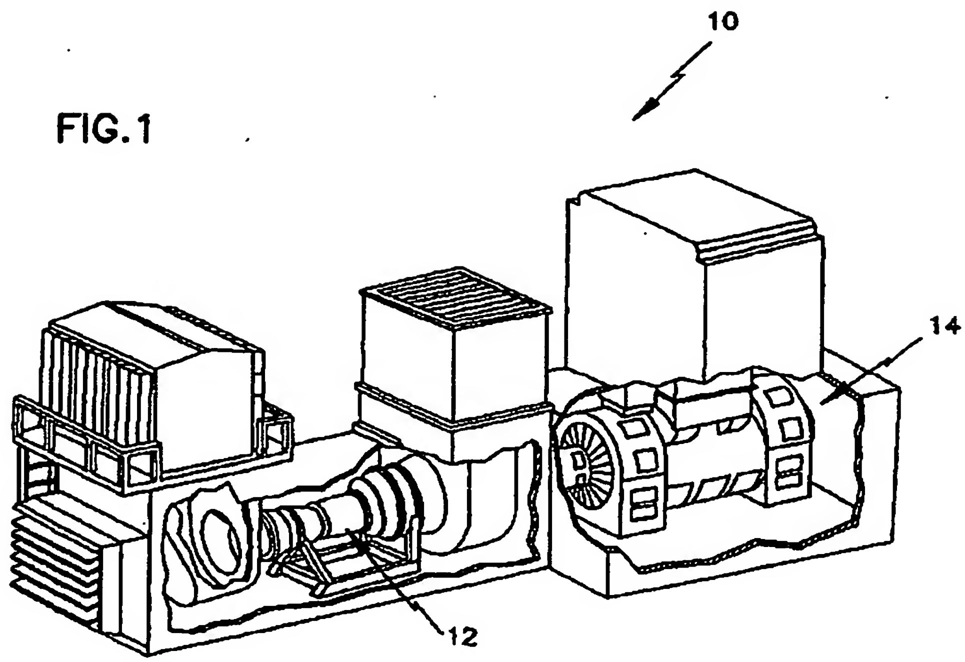
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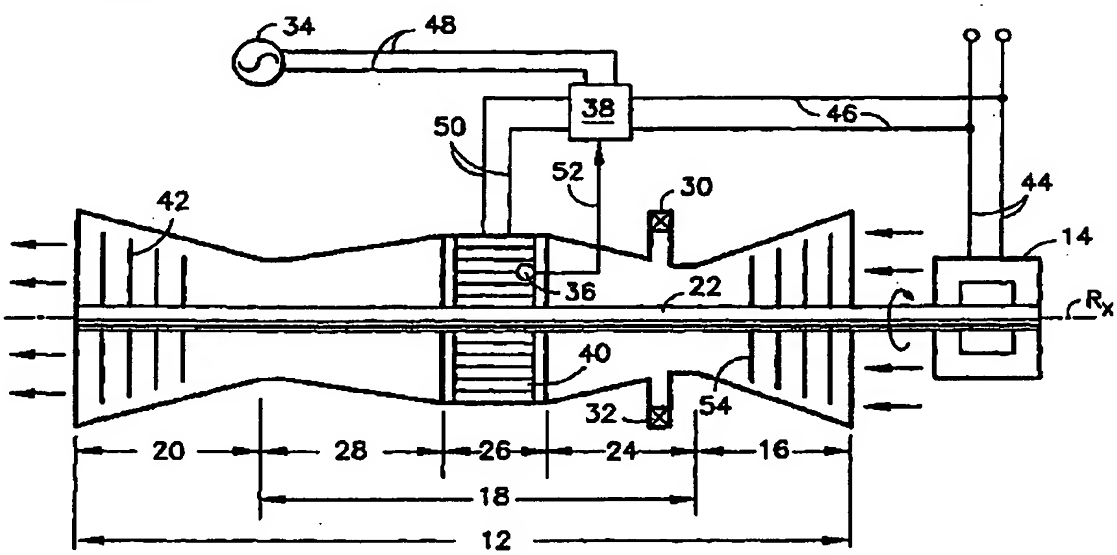
FIG.2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